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ABSTRACT: Soil types were characterized by microbiological sampling at monthly intervals, for at least one year, of various horizons of a cut at the site, down to a depth of about 50 cm. By plotting the numerical results of these cycles of mass changes, curves were obtained which give characteristic pictures of the soil types.

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At the center of the present investigation is the question: "Is there a microflora which is characteristic of certain types of soils by its species balance, its mass development, and its activity?" This subject has already formed the starting point of more or less extensive investigations within recent decades. Only a few authors will be mentioned here, without implying that this series claims to be complete, whose observations were concerned with the solution of the question of microflora specific to a soil type. These are Aristovskaya (1957), Crawford (1956), Dreves (1928), Ducker and Leenan (1957), Dueggeli (1925, 1928), Johann (1932), Katznelson (1957), Feher (1933), Kostiuk (1930), Kox (1954), Krassilnikow (1957), Krehl and Nieffer (1950), Mirchink (1957), Niethammer (1937-1942), Ordin (1956), Starc (1942), Samzjewitsch (1955), Szilvinyi (1934), Verona (1934), Michoustin (1957), Waksman (1916-1950). Of course, there is a question of method connected with the above named problem, which also forms the title of the present article, "How can soils or soil types be characterized microbiologically?"

The points of view, the methods, and ways of attaining this objective are quite variable. The most important ones will be outlined here briefly.

1. Microbiological characterization of soils by the determination of the germ number.

This oldest path was explored at the end of the preceding century with the first experiments of a microbiological comparison of various soils. The advantages and disadvantages of the individual methods will be described in the

*Numbers in the margin indicate pagination in the foreign text.

chapter on methodology. It may be said in summary, however, that the results, or the magnitude of the numbers, respectively, depend on the methods employed, and that only the results obtained by the same method are comparable.

2. Characterization of soils by the occurrence of certain micro-organisms or groups of organisms.

In order to attain the objective one may proceed in such a way as to attempt to determine micro-organism communities or associations, respectively, or to be satisfied with the investigation of the distribution of individual "key forms" on various soil types. In both cases the microbiological characterization of the soil may be supplemented by the observation of the accomplishment of the in- /39
dividual species and degree of their activity. The same objective is served by the quantitative determination of the "physiological groups".

3. Characterization of soils by the determination of microbiological differences parallel to the structure of the soil profile.

In the older studies on soil microbiology, generally only the humus horizon or the upper soil layers were considered. However, an investigation of the total profile yields quite a different picture, which is far more specific for the soil type. Only in this way may the biological control or influence on the soil dynamics be recognized, as was shown in recent years by Aristoyskaya's work with podsols.

4. Microbiological characterization of the soils by determination of periodic variation in soil life during the course of the year.

Although individual samples may disclose a great deal about the microbiology of a soil or site, they are, however, insufficient for the determination of all properties of soil life. The composition of species, as well as the population density of the soil microflora, vary periodically during a year, corresponding to the ecological conditions. Although Waksman (1916), Feher (1933), and Hopf (1950) had previously confirmed this fact, it was only recently that Samzjewitsch, Katznelson, Jerschow, and others determined the specific nature of this phenomenon for certain soil types or soil type groups. Our own observations confirm this view.

The points of view cited were all considered in equal manner for the present work in order to arrive at the most complete characterization of the soils.

It must further be observed here that the taking of soil samples from the chosen sites was done from all depths or horizons of the profile, and at the most regular possible intervals (monthly) throughout the year. For the choice of sites we made certain that several sites were always investigated for each soil type, which showed local, geologic, climatic, and vegetative variations. The microbiological treatment embraced the determination of germ numbers, the actual concentration of the various physiological groups, the composition of the species of microflora, and the quality of the individual species. In the discussion of the results it will be shown in greater detail how and how the observations were carried out.

II. Method

A more detailed description of the methods, both the microbiological as well as the soil science, will be dispensed with here due to lack of space. The numeration of the methods employed will therefore only be supplemented by brief reference.

A. Soil Investigation

A series of investigations were required for the support of the profile descriptions. Their results are reproduced in the Appendix at the site characterization, namely in the order in which the methods are mentioned.

1. Determination of the granular size or sedimentation analysis.

The preparation of the samples was carried out with sodium pyrophosphate, the further work up according to the pipette procedure of Koehn.

2. pH determination /40

The pH values given were measured in KCl with glass electrodes (soil: KCl = 1:2.5)

3. Lime or carbonate determination.

In most cases a determination with the Scheibler apparatus is sufficient (volumetric determination of the generated CO_2). The determination of higher lime content was carried out gravimetrically.

4. Humus determination or determination of organic substance.

For humus contents up to 7%, the accuracy of the Walkley-Armstrong-Black method is sufficient (wet incineration and backtitration of the unconsumed chronic acid with Mohr salt). For higher humus contents, the organic carbon was determined by elementary analysis with the Dennstedt apparatus.

5. Determination of the cation sorption capacity, or exchange capacity, respectively, T-value or UK-value.

The fast method according to Ulrich (1954) proved to be best suited for the present investigations. This was substituted with ammoniam salt in the alkaline range. The values given are in milligram equivalent (mgeq) per 1h0 g soil.

6. Determination of the S-value.

In many cases the method of Kappen 192 was sufficient. This was interchanged with n√10 HCI. The values given are in mgeq/100 g soil.

7. The calculation of the degree of base saturation or V-values is obtained by the formula $S \cdot \frac{100}{T} = V\%\ T = UK$

B. Microbiological Methods

The following microbiological investigations were carried out on each soil sample taken.

(1). Determination of the germ number (aerobic bacteria and activomycetes, fungi, anaerobic cells). (2). Qualitative and quantitative determination of the most important physiological groups. (3). Qualitative analysis of the microflora and further testing of the performance of individual organisms. More detailed descriptions of the working procedures and nutrient media compositions may be found in the handbooks and methods of the following authors: Loehns (1920), Kraus and Uhlenbusch (1924), Janke (1928), as well as Pochon (1954).

1. Determination of the germ numbers.

For this purpose equivalent amounts of soil samples are suspended in sterile water, shaken, and are placed in various dilutions on agar plates or mixed with agar. The basis for the preferences of the plating method

versus other procedures of direct computation was the good reproducibility and the possibility of directly differentiating different organisms, and for inoculation for possible further culturing. For the same reason, the methods of Cholodny, Ziemicka, Chester, and others were not employed. The curves in Chapter IV reproduce average values of the counts on soil extract agar according to Wiltgen and Bonnier (1952). Experiments were made in many series with additives to this agar (fluorochrome, antibiotics, and others); they are supposed to suppress the bacteria and make possible the exclusive growth of the fungi; however, their results were not considered here. The additives, namely, also hindered the growth of various fungi. The anaerobics were grown in Burry tubes.

2. Determination of the physiological groups. /41

1. Cellulose decomposing agents, aerobic and anaerobic

Four methods were tested in several series.

a). Embedding of a cellulose (paper) filter in glucose-poor, or glucose-free agar. b). Mixing of agar nutritive medium or silica gel with cellulose paste. c). Standard method according to Pochon (cellulose suspended in nutritive solution). d). Modified method according to Iterson.

In the present case, the last method was the most useful. The small apparatus required for this is reproduced in a drawing, Figure A. The counting of the places of decomposition on the cellulose filter (see Figure) was facilitated by the use of the reaction with chlorzinc iodide. Besides this, in many cases it was possible to obtain the first isolation of certain organisms by this method.

2. Denitrifying agents.

The same apparatus could be used for breeding as for the cultivation of anaerobic cellulose decomposers. The nutritive solution corresponded to the specification according to Iterson (1904). A chemical screening of denitrification was carried out along with the continuing bacteriological procedure. The methods of Beijerink (*Bakt. Zal.*, Vol. II, No. 1, p 58) were used experimentally in a few series.

3. Nitrifying agents.

The breeding corresponded to the directions of Loehnis (1920). In any case this group was only used for orientation, since the investigations were not carried through at all sites for the whole year.

4. Non-symbolic nitrogen fixing agents.

The directions for the liquid cultures are given by Loehnis, those for silica gel by Pochon (1954). The first method proved to be better. As source of carbon, mannite was used for azotobacher, and glucose for clostridien.

5. Pectin decomposing agent.

The method corresponded to the procedure of Wieringa (1955). The counting of the colonies on the pectin agar plates was usually made more difficult by the formation of fungal veil; therefore the exact reproduction of quantitative results are dispensed with in Chapter V.

3. "Qualitative analysis" of the microflora

The shortage of space does not allow a description of the procedure of determination of the individual micro-organisms in this case. However, this procedure is described in sufficient detail in all process books of microbiology. The bases for the nomenclature employed are from the handbooks, or books of determination, respectively of Gilman (1957), Reper-Tom (1948), Zycha (1937), Wollenweber (1935), and Bergey (1957 and 1950). The monographs (Linnemann) and single publications of more recent date were used for the determination of individual species. The breeding of the micro-organisms for this purpose were carried out on the nutritive medium and according to the methods described in the literature cited.

III. Site and Profile Descriptions

In the first place, those sites are to be summarized here for which completely investigated yearly cycles are available. The brief description of the sites and soil types follow, corresponding to the compilation of the places /42 where samples were taken for the area of investigation. In any case, all the profile descriptions cannot be reproduced here either, only single characteristic examples for each soil type. Due to lack of space, the following specifications

must remain without description for a large number of sites. The following areas of investigation are of particular significance.

Area of Investigation Duerrwien.

The sites are north of Duerrwien in the Flysch zone of the Vienna woods. The The profiles II, I, VII, VIII, and IX are podsols on Greifenstein sandstone under pine stands *(Pinus silvestris)* on a west slope. The opposite flatter slope is covered by a mixed growth of beech and pine forest over various markedly formed pseudogley on clay. The valley ground is filled out with a small meadow on gley soil.

Profile Duerrwien II. Secondary podsol from a sol lessive.
Southwest slope of a *Pinus silvestris* stand of second growth.

Profile:

Aoo + Ao	1.5-0 cm fir needles and Ericacee leaf residues.
A_{11}	0-9 cm strongly humus enriched, weakly loamy sand, humus mould, intensively penetrated by roots Color: dry 10 YR 5/3, moist 10 YR 2/2
A_{12}	9-14 cm humus enriched, weakly loamy sand, humus mould, granular to single grain structure, strongly rooted through Color: dry 10 YR 5/1, moist 10 YR 3/1
A_{2e}	14-40 cm weakly loamy sand with fleecy penetration of humus, single grain structure, less rooted than A_1
B_z	40-50 cm weakly loamy sand, granular to single granule structure Color: dry 10 YR 6/6, moist 10 YR 5/8
C	55 cm and deeper, Greifenstein sandstone

RESULTS OF ANALYSIS

Depth	Grain Size (%)				pH	Humus	S	T	V
cm.	R	Z	Fs	Gs		%	mgeq		%
2—8	—	—	—	—	3.4—4.2	30.0	9.8	80	12.5
10—11	2.2	16.8	54	30	3.5—4.2	6.0	3.0	30	10
20—30	2.0	10.0	55	33	3.6—4.2	0.4	0.1	10	1
40—45	5.7	9.3	53	32	3.9—4.6	0.1	4.0	31	12.9

Profile Duerrwien IV, Pseudogley

Flat knoll and eastern slope, northerly Duerrwien. Beech-pine mixed forest.

Profile:

Ao + Aoo — 1-0 cm foliage litter, partly decomposed, thin layer coarse mould

A_{11} — 0-4 cm strongly humus enriched sandy loam, form of humus mouls, granular to crumbly structure, well penetrated by roots
Color: dry 10 YR 6/2, moist 10 YR 4/2

A_{12} — 4-18 cm slightly humus enriched sandy loam, humus farm mould, indistinct block structure, less root structure than A_{11}
Color: dry 10 YR 6/3, moist 10 YR 4/3

g_1 — 18-38 cm yellowish brown spotty sandy loam, block structure, slight root structure
Color: dry 10 YR 7/4-8/6, moist 10 YR 4/4; spots dry 10 YR 6/6, moist 10 YR 4/4-3/4

g_2 — 30-50 gm yellowish brown spotty sandy loam block structure. More spotty than g_1, slightly penetrated by roots, increasingly stony towards the bottom
Color: dry 10 YR 7/4-8/6, moist 10 YR 5/4; spots dry 10 YR 6/6, moist 4/4-3/4

C — 50 cm and deeper clay

RESULTS OF ANALYSIS /43

Depth cm	Grain Size (%) R	Z	Fs	Gs	pH	Humus %	S	T mgeq	V %
1—3	8,0	23,0	56	13	4,8—5,4	10	19,0	45	42,2
4—10	12,5	27,5	53	10	4,8—5,1	4,1	14,0	31	45,1
18—21	13,5	25,5	50	11	4,8—5,0	0	10	28	35,0
35—40	16,3	21,2	49,5	13	4,6—5,0	0	—	—	—

Profile Duerwien V. Underground water gley on clay, valley ground northerly Duerwien, Magnocasicetum

Profile:

Aoo + Ao — 0-2 cm dense felt of roots, rhizoids and plant residues

A_1 — 2-20 cm strongly humus enriched sandy loam, humus form mould, fine crumbly structure, moderate to well penetrated by roots
Color: dry 2.5 Y 6/2, moist 2.5 Y 3/2

$G_o r$ 20-45 cm gley spotty sandy loam, structure slightly angular, blocky, poorly rooted
Color: dry 2.5 Y 7/2, moist 2.5 Y 4/2-3/2

C 45 cm and deeper, clay

RESULTS OF ANALYSIS

Depth cm.	Grain size (%) R	Z	Fs	Gs	pH	Humus %	S mgeq	T	V %
2—6	9,0	13,5	68,5	9	5,4—6,3	6,8	17	34	50
35—40	10,5	8,5	63,0	18	5,2—5,7	0,3	5,5	15	36,3

Region of Investigation Schrems-Kollersdorf (Forest quarter, lower Austria)

The investigated sites are north of Schrems near Kollersdorf in an old district of Moldanubicums on eisgarn granite. It concerns a podsol under a pine-fir stand (Profile III) and a pseudogley (Profile IV) under nardus heath of part peat and part mineral soil. The region belongs to the zone of humid climate.

Profile Schrems III, podsol on eisgarn granite.
Under pine northeast of Kollersdorf.
Profile:

Aoo + Ao 5-0 cm pine needles and leucobryum cushion, with coarse mould strangely felted with roots

A_1 0-5 cm strangely humus enriched loamy sand, single grain structure, well felted with roots
Color: dry 10 YR 4/1, moist 10 YR 2/2

A_{2e} 5-17 cm loamy sand, moderately rooted through, single grain structure
Color: dry 10 YR 7/3, moist 10 YR 4/3

B_{12} 17-25 cm weakly clayed sand, single grain structure, distinctly darker than B_2 by iron admixture, moderately rooty
Color: dry 10 YR 5/6, moist 7.5 YR 3/2

B_2 25-45 cm loamy sand, single grain structure, moderately rooty
Color: dry 10 YR 6/6, moist 7.5 YR 4/4

BC 45-50 cm granite fines with large rock fragments

C 50 cm and deeper, eisgarn granite

RESULTS OF ANALYSIS

Depth cm.	Grain Size (%) R	Z	Fs	Gs	pH	Humus %	S mgeq	T	V %
5—0	3,0	13,0	—	—	3,2—4,2	30—45	8,8	82,0	10,5
0—5	7,0	4,5	20,0	68,5	3,2—4,5	7,0	0-6	22,5	2,2
5—17	6,3	3,7	17,0	73,0	3,3—4,4	0,3	0,1	20,0	0,5
17—25	11,0	5,5	17,0	66,5	3,6—4,6	0,2	4,0	32,0	12,0
25—45	8,0	7,5	83,5	68,0	4,0—4,7	0	2,0	21,7	9,5

Region of Investigation Southern Vienna Woods (In the neighborhood of Vienna, lower Austria) /44

The region is situated in the pannonic climatic range. The soils investigated are rendzina fumaneto stipetums (forest heath), as well as terra fusca on principally dolonite under beech (fogeto allietosum).

Profile Perchtoldsdorf I, mouldy rendzina.

Under dry sod on flat east slope, western Perchtoldsdorf.

Profile:

Aoo + Ao — 1-0 cm plant chaff, distinctly recognizable plant residues penetrated by small animal droppings

A_1 — 0-20 cm strongly humus enriched loamy sand, humus form rendzina mould, fine crumbly structure, dry, easily broken up well rooted, and penetrated by few chalk granules
Color: dry 10 YR 4/2, moist 10 YR 2/2

AC — 20-24 cm strongly humus enriched loamy sand, well to moderately rooted, greatly penetrated with dolomite fines and small dolomite fragments

C_1 — 24-30 cm dolomite fines

C_2 — 30 cm and deeper mainly dolomite, partly cracked, weathered

RESULTS OF ANALYSIS

Depth cm.	Grain Size (%) R	Z	Gs+Fs	pH	$CaCO_3$ %	Humus %	S mgeq	T	V %
2—8	17,3	29,3	53,7	7,0—7,1	37,4	26,1	74	74	100

Profile Perchtoldsdorf VI, terra fusca on main dolonite

Ravine between Bierhauselberg and Parapluiberg west of Perchtoldsdorf

Profile:

Aoo + Ao — 1.5-0 cm beech foliage litter on a thin layer of coarse

mould, penetrated in a few places by fungal mycelium

A_1E 0-8 cm humus enriched clayey loam, humus form mould, granular to indistinctly polyhedral structure, well rooted through
Color: dry 10 YR 3/3, moist 10 YR 6/4-5/3

E 8-30 cm clayey loam, polyhedral structure, less rooty than A_1E, single fissures covered with fungal mycelium in the upper part of the layer
Color: dry 10 YR 6/4-6/6, moist 10 YR 6/4-5/6

ED 30-35 (40) cm clayey loam, polyhedral structure, moderately rooted, detached dolonite chips
Color: dry 10 YR 6/4, moist 10 YR 5/4-5/6

RESULTS OF ANALYSIS

Depth cm.	Grain size (%) R	Z	Fs	Gs	pH	$CaCO_3$ %	Humus %	S mgeq	T	V %
0—3	38,5	30,0	27,5	4,0	5,6—6,1	0	7,8(8,3)	17,5	37,3	47,0
20—30	39,5	31,0	15,5	14,0	5,5—5,9	0	0,5	15,0	36,0	41,6

Region of Investigation Auen der Donau near Vienna.

The sites on the gravel of the Prater terrace in the region of the high hardy meadow were investigated particularly closely.

Profile 1 Prater near Vienna. Brown meadow ground, high rough meadow

Profile:

Aoo + Ao 1-0 cm foliage litter, slightly decomposed, in between not always clearly recognizable small animal droppings and earthworm crumbs

A_1 0-12 cm strongly humus enriched sandy loam, detached grain structure to fine crumbs, humus form mould, well rooted through
Color: dry 10 YR 5/2, moist 10 YR 2/1

(B) 12-45 cm loamy sand, detached grain structure, well rooted /45
Color: dry 10 YR 7/3, moist 10 YR 5/2

D 45 cm and deeper gravel of the Prater terrace

RESULTS OF ANALYSIS

Depth cm	Grain size (%) R	Z	Fs	Gs	pH	$CaCO_3$ %	Humus %	S mgeq	T	V %
2—8	6,0	20,5	68,5	5,0	7,0	20,7	6,3	35,0	35,0	100
20—30	5,5	12,5	79,2	2,8	7,0	24,8	0,6	14,0	14,0	100

Region of Investigation Nordburgenland (Basin of the Neusiedler See and Parndorf plateau)

The region belongs to the pannonic range of climate. The Neusiedler See is situated in a tertiary penetration basin with the Leitha Mountains as northwesterly framing (crystalline with rounded superposition of marine limestone). The Parndorf plateau forms the north and northeast shore of the basin. The tertiary sediments of the fluvioglacial gravel is piled up here and partly covered by loess. East of the lake near Podersdorf, Apetlon, and St. Andrae, lies the region of the salt earth. Two of the investigated regions were situated near Windne, namely a mull rendzina on Leitha limestone at the foot of Mount Hackel and a Xerorank on quartz phyllite on the mountain itself. Solonchak site lies north of Illmitz and a chernozem in the region of the Zitzmannadorf meadows north of Podersdorf. Only the parachernozem plains on the Porndorf plateau were investigated in several yearly cycle.

Profile district Neusiedl I Hackelsberg, Mullrendzina on Leitha limestone under dry sod (stipa capillata-flur), slight northwest slope.

Profile:

Aoo + Ao	1-0 cm plant chaff and greatly decomposed vegetation residues, penetrated by mite droppings, in places much earthworm crumbs
A_1	0-20 cm strongly sandy, strongly humus rich loam, humus form mould, fine crumbly structure, well rooted through Color: dry 10 YR 3/2-4/2, moist 10 YR 2/1
AC	20-25 cm strongly humus enriched sandy loam, humus form mould, fine crumbly structure, well rooted through, greatly penetrated by limestone fines and chips
C_1	25-35 cm worked-up yellowish colored Leitha limestone
C_2	35 cm and deeper compact, or secondary compacted Leitha limestone

RESULTS OF ANALYSIS

Depth	Grain size (%)				pH	$CaCO_3$	Humus	S	T	V
cm	R	Z	Fs	Gs		%	%	mgeq		%
2—8	12	16	62	10	7,0	3,0	18,5	65	65	100
15—20	—	—	—	—	7,0	30,0	18,0	65	65	100

Profile district Neusiedl II (Hackelsberg), Xerorank on quartz phyllite Knoll of mountain vegetation Fumanetostipetum and Medicageto Festucetum

Profile:

Aoo + Ao — 1-0 cm thin layer of plant chaff, in part penetrated by mite droppings

A_{11} — 0-25 cm humus rich loamy sand, humus form mould, fine crumbly structure, well rooted through
Color: dry 10 YR 4/2, moist 10 YR 2/2

A_{12} — 25-35 cm coarser crumbly than A_{11} and greatly penetrated with rocks and fines, otherwise like A_{11}

AC — 25-50 cm slightly humus enriched sand, frequently penetrated by sharp edged stones and fines

C — 50 cm and deeper, quartz phyllite, friable in a few places

RESULTS OF ANALYSIS

Depth cm	Grain size (%) R	Z	Fs	Gs	pH	Humus %	S	T mgeq	V %
2—6	2,5	17,5	67,4	12,6	5,8	8,5	19,7	30,0	65
6—15	2,6	11,9	66,6	16,9	5,8—6,1	8,3	19,8	30,1	65,6

Profile Parndorf IV, Paracernozem under dry sod (top meadow) /46

Profile:

Aoo — 2.5-2.0 cm plant chaff

Ao — 2-0 cm strongly humus enriched sand, humus form mould (moder), interfelted by roots

A_{11} — 0-7 cm moderately humus enriched sifted sand, humus form mould (mull), indistinct fine crumbly structure, well rooted through
Color: dry 7.5 YR 4/4, moist 7.5 YR 2/2

A_{12} — 7-30 cm moderately humus enriched fine sandy loam, humus form mould (mull), very indistinctly fine crumbly, moderately rooted through
Color: dry 10 YR 4/2, moist 10 YR 2/2

AD — 30-40 cm moderately humus enriched fine sandy loam, lightly rooted through, penetrated by stones of the gravel cover
Color: dry 10 YR 4/2, moist 10 YR 3/2

D — 40 cm and deeper, quartz rich gravel

RESULTS OF ANALYSIS

Depth cm	Grain size (%) R	Z	Fs	Gs	pH	Humus %	S mgeq	T	V %
2—0	—	—	—	—	5,6	11,5	—	—	—
2—7	14,0	23,5	30,6	7,0	5,7	3,9	24	32	75
25—30	15,0	30,5	47,5	7,0	5.6	2,3	17,2	22	78.1

Region of Investigation Wilfersdorf (Lower Austria, wine region)

The region is a tertiary hilly country with loess drifts and belongs to the pannonic range of climate. The site is old cultivated land.

Profile Wilfersdorf I, Chernozem, south of Wilfersdorf, 1958 under barley, 1959 under rape.

Profile:

A_{1p} 0-16 cm humus rich fine sandy loam, humus form mould, fine crumbly structure, well rooted through
Color: dry 10 YR 4/2, moist 10 YR 3/2

A_2 16-35 cm sandy humus enriched loam, humus form mould, structure indistinctly blocky, well rooted through
Color: dry 10 YR 4/2, moist 10 YR 3/2

AC 35-45 cm weakly humus enriched sandy loam, angular fine blocky, well rooted through, with admixture of earthworms and pseudo mycelium

C 45-185 cm loess with pseudo mycelium penetrated by detached (odd) earthworm tubes, root canals, narrow transition to tertiary sand

D 185 cm and deeper, tertiary sand with distinct edging of gravel

RESULTS OF ANALYSIS

Depth cm	Grain size (%) R	Z	Fs	Gs	pH	$CaCO_3$ %	Humus %	S mgeq	T	V %
0—10	30,0	30,0	38,4	1,6	7,0	1,2	2,56	26	26	100
20—30	28,5	30,5	40,0	1,0	7,0	1,5	2,42	26	26	100
35—10	30,5	33,0	35,7	0,8	7,1	1,6	2,00	33	33	100

In assembling the list of species and the reproduction of other results, the following sites were also considered; these were not named in the chapter on site description.

1. High bog: Ratmoos-Weichselboden, Hochtensechochmoor (all in Styria), Nabkorhochmoor (lower Austria) Haslauer Moor

2a. Brown meadow land: Auen der Donau bei Orth and Fischamend (lower Austria)

2b. Grey meadow land: Auen der Donau bei Orth, Tulln, and Vienna

3. Solonchak: Salzsteppe bei Illmitz (Burgenland)

4. Gley: Derrwien, Profile VI

5. Ranker: Koenigswart bei Hainburg (lower Austria)

6. Mould-like rendzine: Frauenstein bei Moedling, Hundscheimer Mountains (lower Austria)

7. Mould rendzina: Hundsheimer Mountains (lower Austria)

8. Chernozem: Braunsberg (Hainburg, lower Austria), Parndorf, Gerhaus (Burgenland), Marchfelt (lower Austria), several places /47

9. Parachernozem: Neudorf (Burgenland), Obersiebenbrunn (lower Austria)

10. Terra fusca: Anninger (lower Austria)

11. Oligotrophic brown earth (northern Vienna woods), Profile HB I-IV

12. Pseudogley: Schrems, Profile V, Duerrwien, Profile VI, Wieselburg Profile I and II (lower Austria)

13. Semipodsol: Schrems Profile VI and VII, Moenichkirchen Profile IX and X

14. Podsol: Amaliendorf Profile I and II, Moenihkirchen Profile VI (all lower Austria)

15. Loess brown earth: Hundsheimer Mountains, Zeilerberg (Burgenland)

IV. Mass Exchange of Microflora in Annual Cycle

The microbiological characterization of sites or soil types on the basis of a single sample could hardly yield a complete picture. For the proper determination of the microbiological properties it is necessary to follow one, or still better, several "yearly cycles". This means that in the course of a year, if possible every four to five weeks, samples should be taken for investigation from all horizons of the soil. Even with a single sample removal, significant variations in germ content may be shown in the various soil horizons according to the soil type. It may be shown, except for extremely dry periods, that the upper layers contains much greater numbers of germs than the deeper layers. This may in part be explained by the fact that in the upper

layers the humus content, as well as the oxygen content of the air in soil airspaces, is greater and is the greatest part of the microflora determined by standard methods is aerobic as well as heterotrophic. Aeration and humus content of the soil have an appreciable effect on the microbe density of the soil; also the nutritrient content and water content variations are decisive for the periodic variations of germ numbers.

The total number of germs in the soil vary during the course of the year in a manner quite characteristic for the climate and type of soil. Waksman, Feher, Hopf, Samzjewitsch, Katznelson, Jerschow, and others have already made observations in this direction, and verified by examples, which in any case, generally do not classify the sites according to soil type. The periodic variations of the population density become particularly clear with the graphic representation of the computational results according to the plating method. The course of such curves are characteristic of the soil types or rather for certain "ecologic groups" of soil types and even for smaller and larger regions of climate. The comparison of these "total germ number curves" of soils yields a grouping into "microbiologic-ecologic type groups". This realization will be considered for the description of the results. The sites or soil types will be summarized into such groups during the discussion, insofar as they deal with sites investigated for a full year. Only a very small selection of the curves can be reproduced due to lack of space (Figures 1-5).

Group I

Soils on moderate to extreme xerothermal sites of pannonic area or of climatically similar places.

These are soils with a relatively shallow and well-aerated A-layer, often only a few centimeters thick. To these belong xeroranker, protorendziva, mould-like redzina, and mould rendzina of the pannonic region. The total germ numbers (particularly bacteria and activomycetes) show two maxima in their mass development during the course of a year, one in the spring and a second in fall or late /48 fall. In between there is a depression which reaches its lowest point in June or in the first week of July. Hopf (1955), Samzjewitsch, as well as Katznelson and Jerschow (1957) have made this observation in the same way. Varga, Gunhold, Franz, and Boyer have also established such a summer depression for the mass

development of soil fauna in pannonic area. The curves for the yearly cyclic mass development of the fungi appear very similar to the bacteria curves, although in this case the variation in the development of the fungi colonies on the plates made the calculation difficult. The anaerobics show a similar course of development even though the first maximum appeared earlier, in April. A comparison of the mass change curves with the corresponding plotting of the actual water content shows the significance of this factor by certain parallels.

Group II

Steppe soils of the pannonic area Chernozem and Parachernozem. These are soils with AC or AD profiles. The humus content is mostly lower than in the soils of the previous group. But the sandy and well-aerated A-layer is considerably deeper.

The mass change curves for bacteria shows in the upper 2-3 dm of the soil the same course as for Group I. The consequence of the summer drought at greater depths is minimized, which may also be seen in a sample curve. The summer mass development decline for fungi may still be well observed at depths of 40-50 cm. As for the fungi, the anaerobics may be readily recognized in the upper 3 dm at the equivalent period of mass change as for the microflora of Group I. The decrease of the anaerobic numbers at greater depths is less readily observed. The effect of the variation of actual water content is the mass change in the same as mentioned for Group I.

Group III

Alternating moist soils, pseudogley .

The yearly cyclic total germ number curves show a distinct difference between higher and deeper soil layers. The two-peak curves of the upper 10 to 20 cm again yield a light summer depression. At lower depths, particularly in the gley layer, the numbers reached in the summer stay longer at the maximum height. It could also be observed that in green land soils (Schrems, Profile IV), the summer depression starts earlier than in the overshadowed forest soil. For the fungi, the summer regression of the mass change in the higher layers is much greater than for the bacteria; this was also observed by Krzemieniewska (1954). In the gley horizons there is only a clear fungus maximum in the spring. The mass develop-

ment of the anaerobic germs shows a great similarity to the fungi in their graphic representation. The variation of the actual water content, summer drying out in the upper cm, also significantly affect the mass exchange in this soil.

Group IV

Lastingly moist soils of the humid climate: gley, various peat bogs ("Anmoor, Flachmoor, Hochmoor").

Here no summer depression in the development of bacteria and activomycetes can be observed even in the upper cm. In the deeper horizons the total number of aerobic germs are already so low that a clear maximum cannot be observed. The maximum for the upper horizons may usually be observed in June. There is only sufficient oxygen in the air in the upper cm of the soil for the growth of most fungi; the maximum development occurs here mostly during June. The development of the anaerobics proceeds quite differently. Two maxima occur in the upper layers, one in May and a second in October, but further down only one maximum in the summer. The temperature factor must here be of greater influence than the actual water content for the microbe development in the upper horizons.

Group V

More or less sandy soil without summer periods of drought, podsol, semi-podsol, grey and brown meadow soil, oligotrophic brown earth.

The mass development of bacteria and activomycetes in the horizon reaches its only maximum in these soils, as a rule, in June or July; however, in the Aoo and Ao horizon this often occurs in May. In the mineral layers, the variation of the smaller numbers is less. For meadow soil the bacteria numbers appear to remain in these layers for a maximum of several months. In all layers, the fungi development attain their maximum before the bacteria. In the A_1 and B_s layers of the podsol a second fungi maximum may also be observed in the fall. The mass change of the anaerobics is characterized by two maximum, the first in May or April, the second in September or October. Distinct parallels between variation in water content and mass development could not be recognized.

Group VI

Loam soils of the pannonic climate region, Terra fusca

The mass change of the bacteria and activomycetes shows only one maximum in all layers during the course of the year. However, a slight summer depression may be observed in the upper 5 cm of soil in years of extreme periods of draught. The yearly cyclic curves of the total fungi numbers show in the summer in the humus layer and in the upper cm of the mineral layer a distinct depression as a result of drying out. This may no longer be observed at the 35-40 cm depth; here the number stays a longer time at its maximum. The development of the anaerobics also shows two maxima in all layers, one in April and a second one in September, or when it is very dry, in October.

V. The Physiological Groups

The micro-organisms in soil microbiology are compiled in the following groups on the basis of their physiological and chemical activity: (1). Cellulose decomposers; (2). Pectin decomposers; (3). Protein decomposers; (4). Wrea decomposers; (5). Butyric acid formers; (6). Nitrogen fixation; (7). Dentrifying agents; (9). Nitrifying agents.

All groups mentioned will, of course, not be treated with the same precision in this and the following chapters. This procedure should be justified by the composition of the vegetation residues, whose decomposition is carried out by the largest fraction of soil microbes. A few examples of the composition of vegetation residues:

	Oat Straw	Wheat Straw	Pine Needles	Carex Leaves
Cellulose	35%	34%	28%	28%
Pectins & Hemicelluloses (partly non-decomposable)	21%	22%	13%	18%
Lignin	20%	21%	15%	21%
Protein	5%	3%	7%	7%

/50

Protein Decomposing Agents

A comparison of the distribution of the following species in the various soils shows that the individual species of this group are not very significant by

themselves for the soil type (see Table Bacteria I): *Bac. mycoides, B. vulgaris, B. mesentericus, B. megaterium, B. subtilis, Bact. prodigiosum, Pseudomonas fluorescens.* The germs of the group as a whole, behave in their yearly variation in mass development, so as to run parallel to the variation in total germ number. This also corresponds to the observations of Michoustin, Gromyko, Krassilnikow, and others. Further shifts in the composition of species of this group may be determined by the comparison of "natural" soils and cultivated land. Under the species of this physiological group there are also forms which have the ability to hydrolyze starch or to decompose pectin. Pectin decomposition particularly is of great significance for the decay of forest stand waste; this, however, will be discussed in Chapter VI.

Cellulose Decomposing Agents

The enormous importance of this group of organisms within the soil flora can hardly be exaggerated. The bacteria of this group belong to the genera *Cellvibrio* and *Cellulomonas*, the fungi of the most distinct families of ascomycetes and basidiomycetes. Their distribution is shown in the tables (page 66 to page 69); further discussion follows in the next chapter. The quantitative results are reproduced in the form of yearly cyclic curves, as in the preceeding chapter. The discussion that follows deals with the subdivision of the "microbiological ecological soil type groups" (Figure 6,7).

For soils of Groups I and II, the graphic representation of the mass development during the course of the year shows two maxima at all depths of the various soils, the first one in May or end of April, the second one in September or October. For those soils of both groups in which the pH is less than 6.8, the number of anaerobic cellulose decomposers reaches those of the aerobic ones, even surpassing these in a few cases.

In the soils of Group III, the above described high summer depression of the cellulose decomposers is missing at a depth of 40-50 cm, and is even weakened in the upper layers where overshadowed (forest).

In the soils of Group IV the mass development of the cellulose decomposers shows only one maximum in May in the upper cm and in June in the deeper layers.

The sites of the soil type Group V behave quite differently with respect to the yearly cyclic course of development of the cellulose decomposing germs. It may, however, be said in general that the mass development of these organisms shows two maxima in the well aerated humus layers of podsol and podsol-like soils, and only one maximum in the mineral layers. For the meadow soils only one maximum can be clearly recognized in the development of the cellulose decomposers, namely in May or June. These statements are valid both for the aerobic and the anaerobic /51 representatives of this group.

The soils of Group VI also show similar curves for the yearly cycles of the cellulose decomposers. The one clear maximum occurs in June or July for the aerobics and in May for the anaerobics. The overshadowing of the corresponding sites (beeches) must be connected decisively with the lack of a pannonic climate and the corresponding summer depression.

Dentrifying Agents

Only the quantitative results will be discussed for this group. Again we will forego the classification here of the microbiological ecological soil type groups. In all sites of these groups the mass exchange of the denitrifying agents shows two maxima, which are naturally distinct and occur in different months. The graphic representation of the year cycle shows, for soil type Groups I and II, the first maximum in April and the second maximum in October. This also holds for Group III, although here the maxima in the lower layers are not as extreme as in the upper 10 cm. For gley (Group IV) the second maximum in the gley layer is not very clear. Some curves (not all are reproduced) even show that the maximum number of denitrifying agents reaches in March or April are maintained until October. In the A-layer of soils of Group V the denitrifying agents have their first maximum in May, the second in September or October. In the B-layer the reduction between these two points could be very slight ot even be missing altogether. Meadow soils and podsols behave similarly, although the absolute numbers could be quite different. For Terra fusca (Group VI) the relationships in the humus zone are similar. In the mineral layer a second maximum is clearly observable in the fall, which shows higher numbers than the first maximum in the spring (Figure 8).

Independently Living Nitrogen Fixing Agents

This group of organisms has already been treated in great detail in the microbiological literature. Our own investigations can only be considered here as supplementing the already available research results, particularly because some soil types were investigated which had hitherto not been tested.

The subdivision of a few species corresponding to the chemistry and soil type are given in the table (page 23) according to our own observations.

When the forms of these groups of organisms are considered as a whole during the discussion of the mass change, then on one site it concerns only Azotobacter, while on another site by contrast it concerns mixtures of two or less forms of the nitrogen fixing agent clostridien. In the following chapter this will be discussed in greater detail. The observation again follows in the series order of the microbiological ecological soil type groups.

The mass development of these organisms on sites of Groups I and II shows as a rule two maxima in all soil layers, one in May and another in October, both for Aztobacter and Clostridien. For pseudo gley (Group IV), where the nitrogen fixation is accomplished by Clostridien, two more or less clearly developed maxima are shown in the upper 10-15 cm; in the lower layers as a rule only one maximum, mostly in the spring. When we observe at all microbiological N-fixation by independently living organisms for soils of Group IV, at the gley soils, they /52 take place in any measurable amounts only in the upper cm of the soil. These are the Clostridien whose maximum development occurs at the height of summer. For the sites of Group V, definite results are only available concerning Azotobacter from meadow soils. The course of development shows only one maximum in June or July. The Terra fusca of the pannonic region, where the nitrogen fixation takes place largely by Clostridien, shows in the graph of the corresponding yearly cycle curves two maxima, the first in May and a second in September (Figure 9).

VI. Qualitative Analysis of Soil Microflora

The attempt will be made in this chapter to find a characteristic species compilation of microflora of different soil types by the determination of the individual organisms. The activomycetes were investigated only in an orienting manner in this connection, since their systematalogy is still disputed in many

cases. This attempt experiences a completion by the fact that for each species in the corresponding tables its chemical physical performance or capability, is also given, based on our own investigations as well as the literature. Due to the tight frame of the work, the species lists of the individual sites in the tables are summarized in one column according to their relationship to a certain type of soil. A further disadvantage of this brief representation lies in the fact that the yearly time differences, with their characteristic quantitative particulars, cannot be reproduced in the tables. However, this will be briefly summarized as much as possible in the text.

pH Value	8,0				7,0				5,5					3,5
Soil Types;	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Azotobacter chroococcum	+	+	+	+	+	+	+	(—)	(+)	—	—	—	—	—
Azotobacter (compare) agile	+	+	—	—	+	—	—	—	—	—	—	—	—	—
Bacillus amylobacter	—	—	+	+	+	+	+	+	+	—	+	—	—	—
Clostridium sp. sp.	—	—	+	+	+	+	+	+	+	—	+	—	—	—

Soil Types: 1. Solonchak; 2. Mould-like Rendzina; 3. Mull Rendzina; 4 4. Chernozem; 5. Meadow Soil; 6. Terra Fusca; 7. Oligotrophic Brown Earth; 8. Pseudogley; 9. Parachernozem; 10. Ranker; 11. Gley; 12. Semipodsol; 13. Podsol; 14. High Bog.

During the discussion of the individual soil types and their microflora, an ordering following their chemical properties will be arranged as shown below

Humid Climate	pH	CaCo 3%	Humus % Highest Amount
High Bog	3	0	90
Podsol	3—4,5	0	50
Semipodsol	3—4,5	0	40
Gley	5—6	0	10
Pseudogley	5—6	0	8
Oligotrophic Brown Earth	5—6	0	5

/53

Semiarid Climate			
Chernozem	7	2—5	4—6(10)
Rendzina	7	2—35	40 (45)
Meadow Soil	7	2—16	4—6
Parachernozem	5—6	0	4 (9)
Ranker (Zeroranker)	5—5,5	0	15
Terra Fusca	5,5—6,5	0	6 (12)
Solonchak	7,5—8,5	—	0,5—1

The High Bog

The bacterial flora of the high bog is characterized not only by a low total germ number, but also by an extreme poverty in species. Particularly conspicuous is the lack of freely living nitrogen fixing agents and nitrifying organisms. Also the cellulose decomposers among the bacteria are represented only by the genus *Cellvirbio* in very scanty numbers, one or two species. Besides, these forms are on the basis only of single isolations. In this way it was possi-possible to confirm that the slight cellulose decomposition in the bog was due to the fungi. The ecological conditions in the bog are even less favorable to the activomycetes than to the bacteria. Until now no definitely identifiable form could be isolated from the investigated high bog site. A number of characteristic fungi endure much better the given conditions at the site. Of the Mucoriceen, the genus *Mortierella* is represented by a few species. Forms of this genus also appears as Mycorrhiza fungi in *Calluna vulgaris*. Particularly typical for the high bog is also a series of penicillins, particularly those of the Monoverticillata group. First of all it concerns forms which precipitate nominal amounts of acids, dyes, and inhibitors. There are no cellulose decomposers among these species. According to our own observations the genera *Cladosparium* and *Cephalosporium* actively participate in cellulose decomposition in the high bog. Hemicellulose and pectin are attacked by *Alternaria* and various Mucorines. The performance of the fungi mentioned, particularly the formation of the acids and inhibitors, is just as specific for the high bog as the incomplete decomposition of the organic substances. The largest part of these "high bog fungi" are found again in the Biocoenoses of the podsol and semipodsol.

There is already much published work on the microbiology of the high bog (Isotalo (1951), Kox (1954), Drewes (1928), Reuter (1957), Benade (1950)). However, in all these investigations there is a lack of more or less exact description of species, which makes a comparison with our own work impossible.

Podsol

There is already extensive microbiological literature about this soil type, which in most cases is particularly valuable because of the exact descriptions of species. Aristovskaya (1957), Crawford (1956), Ducker (1957), Feher

(1933), Hagem (1907), Jensen (1938), Johann (1932), Katznelson (1957), Krassilnikow, Korenjako, Mirtschink (1955), Lennan (1954), Mekktiev (1957), Mirchink (1957), Starc (1942), and Stephanowa (1958) have made important contributions. The following description is based on our own observations.

The poverty of bacteria species is also typical of the podsol as for the high bog. In any case there are only a few cellulose decomposing species among them, namely from the genus *Cellulomonas*. Free nitrogen fixing agents are missing from the hitherto known genera and species; the same is true of the nitrifying agents. /54 *Bacillus mycoides* is always present. Only a few species of Actinomycetes were isolated. *Actinomyces acidophilus* seems to be particularly typical. Other species of this group of organisms are distinguished by intensive formation of dyes. *Bact. prodigiosum (Serrta mar.)* could also be characteristic for podsol by its intensive formation of dyes, as well as by its abundance at a few sites. Intensive dye production is also characteristic for a few species of penicillum of this Microcoenose. The same species also precipitate acids and inhibitors; they also lack the ability to decompose cellulose. Among the fungi, *Trichoderme, Acaulium,* and *Cephalosporium* are far more actively engaged in cellulose decomposition in this soil. Also among these forms there are again numerous producers of inhibitors. Neither inhibitors nor acids are produced by a few Mucorinees (the genera *Mucor, Mortierella, Zygorrhynchur, Absidia),* which are represented by the same species at all sites, from Croatia to Narvik and Abisko, and this can also contribute to the characterization of podsol. The slight, but for the high bog superior, decomposition of the plant stand trash is typical for the microbiology of the soil, along with the various exudations of the microbes. The acid production is particularly conspicuous because there are here too few bases for neutralizing these compounds. Also a fast microbiotic decomposition, as was observed with other soils, where even oxalic acid is decomposed (Khambata 1953, Muller 1950) was not observed here.

Just as typical as the species composition in the podsol microflora, is the exchange of the periodic annual "aspects". The winter aspect is characterized by masses of penicillins with dye exudations, but *Penicillium canescens, um Trichoderma koningii* and *Acaulium* are particularly dominant in the fall and also in the spring. The summer aspect represents an abundance of certain forms of fungi,

which, however, begin to develop in May and disappear down to a few penicillins at mid-summer in years of great drought. The appearance of any amounts of *Alternaria, Cladosporium* and similar forms also occur during the summer.

Semipodsol

The microflora and microbiology of this soil is similar on the whole to the podsol. Bacteria and actinomycete flora are practically the same for both types. Among the fungi, *Mortierella* become poorer by a few species. The penicillins with dye exudations are not as much in the foreground as for the podsol, but to compensate for this, *Stemphylium, Cladosporium,* and similar forms of *Fungi imperfecti* are more abundantly represented. Most of the "high bog fungi" (penicillins of Monovert group, *Cephalosporium, Mortierella,* and others) can also be isolated from the semipodsol. The annual variation of the microflora ("aspects") is exactly the same as for the podsol, the same is also true for the influence of the site character by the activity and exudation products of the microbes.

Pseudogley

The difference in the species composition of the microflora of this soil versus the already described types is in the fact that the fungal flora are just as great as the bacterial flora. In the first place *Clostridium* can always be isolated from pseudo gley as representative of the freely living nitrogen fixing agents. Also cellulose decomposition is carried out to a considerable extent /56 by bacteria which belong to the genera *Cellvibrio* and *Cellumonas*. Butyric acid formations, which seem to be missing in podsols, may be observed here. According to our own orienting investigations, the actinomycetes flora should approximately represent the oligotrophic brown earth with regard to the species. For the fungi, there are also no "character species" for this soil type in the sense of the sociologist Braun-Blanquet, although *Circinella tenella, Catenularia, Acrostalagmus* and *Cylindricum aeruginosum,* as well as eventually also *Penicillium melinii* came to be considered for it. *Penicillium canescens, Penicillium chrysogenum, Penicillium turbatum,* and *Acaulium alb. nigr.,* besides a few other species of these Mycocoenoses share their properties with the previous soil types. *Gliocladium* is worthy of mention as an added new fungus. Many of the "high bog

fungi" which were still found in the semipodsol, have disappeared from this type. However, the "winter aspect" of the fungi flora reminds one very much on the Mycocoenoses of the podsol by the abundant occurrence of *Penicillium canescens*. The summer aspect with a strong development of *Gliocladium* points in the direction of the pannonic soil microflora. The microbe exudations (inhibitors, etc.) are not as active as in the podsol soil.

Gley

The investigations have up to now not yielded any bacterial flora which would be specific for this soil in its composition. The cellulose decomposing bacteria are represented by several species, also a few anaerobic. They predominate over the greatest part of cellulose decomposition. Only *Clostridium* was found of the bacteria which fix nitrogen. *Azotobacter chroococcum* is missing from this soil, insofar as it is not cultivated. Pectin decomposing organisms are found here both as bacteria and fungi. *Bacillus mycoides, Bacillus mycoides* and pseudo monas occur in large amounts. Nitrosomonas may occasionally be isolated from the upper soil layer. Among the fungi, *Martierella* has here become scarce, in contrast to the heretofore discussed soil types. *Eliocladium* is mostly missing, as well as *Cladosporium, Stemphylium,* and *Alternaris*. The number of "high bog fungi" is greatly reduced. Trichoderme can only be found in the upper cm of the gley soil. There is no formation of inhibitors and acids by fungi to the extent found in podsol soils; these substances may in part become inactive by adsorption.

Viewed microbiologically, gley is differentiated most clearly from all other soils by the extreme anaerobic ratios in the lower layers, whereby the lack of a fungus flora may be explained.

Oligotrophic Brown Earth

Soils which correspond to this type or which are close to it have already been investigated by Krehl, Nieffer, Niethammer, Feher, Bokor, Grundmann, Hopf, Jensen, Kostiuk, Krzemieniewska, Lemmermann, Niklas, Seifert, and Ordin. However, the comparison with our own work suffers from an insufficient description of the profile by these authors.

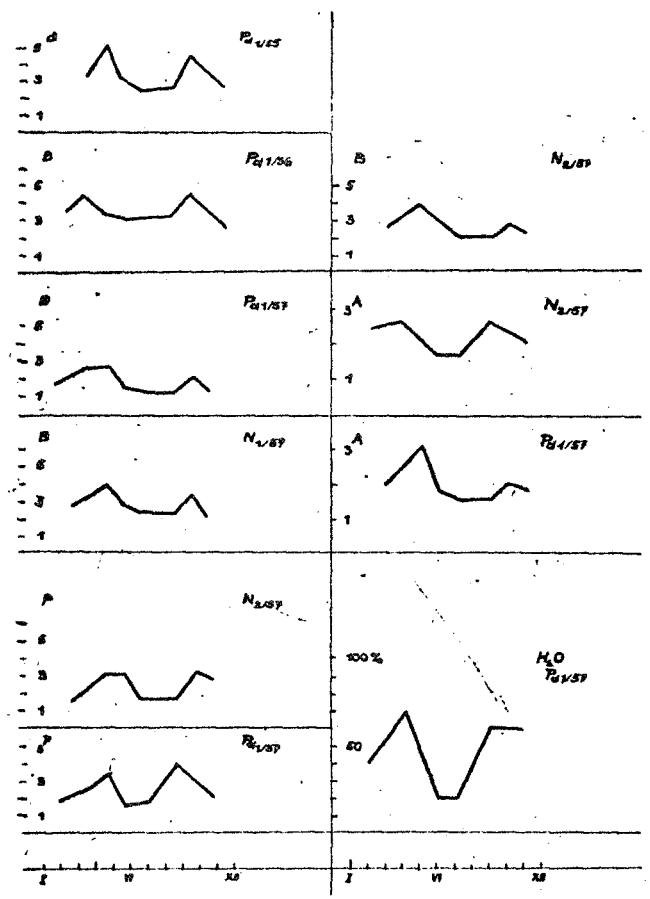

Figure 1

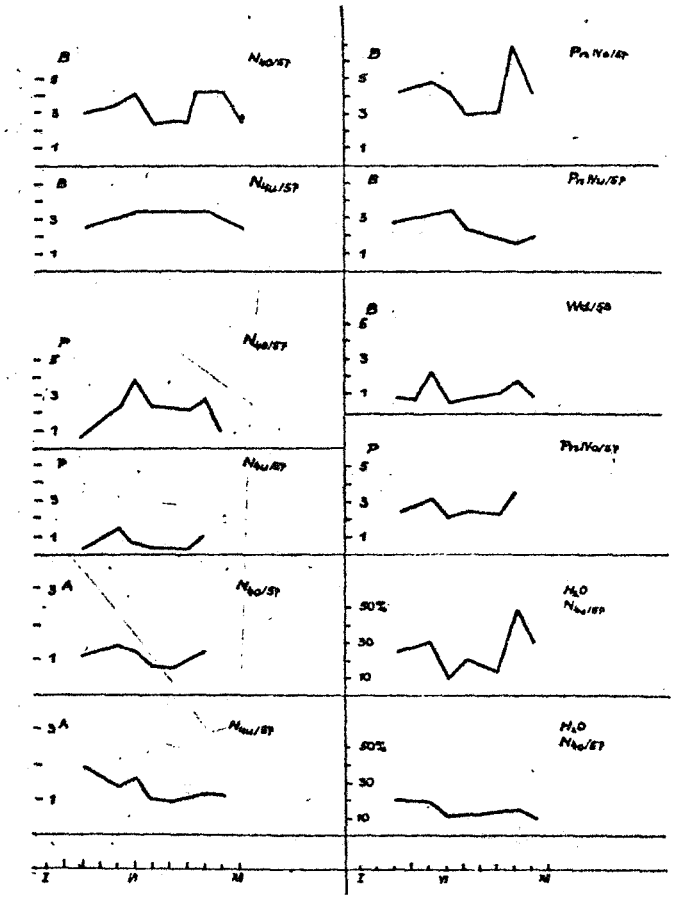

Figure 2

Figure 1 and Figure 2

To The Figure 1-5; Curves for the Changes in Total Germ Number During the Course of the Year.

B = bacteria in millions per 1 gram soil
P = fungi in 10,000 per 1 gram soil
A = anaerobic germs in 100,000 per 1 gram soil
H_2O = actual water content of the soil in %

} Mark Left of the Graph

For the Site Works and General Explanations for Figures 1-9, see

Of the previously discussed soil types, that of the brown earth is differentiated by the isolation of small amounts of *Azotobacter chroococcum* at individual sites. It is also noteworthy butyric acid producers (Clostridium) appear from time to time in large masses. Species of Clostridium, which have not yet been more closely determined, also participate measurably in nitrogen fixation. Cellulose decomposition is dominated to a large extent by bacteria of the genera *Cellvibrio* and *Cellulomonas*. Under the actinomycetes, those with intensive melanin formation are represented abundantly. Otherwise the bacteria flora are not too typical. The fungi of the oligotrophic brown earth remind one of a few forms of the podsol microflora. We also find here again the association of *Trichoderm koningii* and *Acaulium albo nigrescens*. Otherwise the species spectrum is dominated by a number of penicillins. Similar to the podsol, there are also a considerable number of producers of inhibitors and acids among the fungi here. Their influence, however, on the rest of the microflora and on the site itself is much less for the brown earth. /58

Chernozem

Several Russian microbiologists have been intensively preoccupied with this soil type. The work of the following must be mentioned in the first place with regard to the species-wise analysis of the microflora: Chudjakow (1926), Gromyko (1954), Guillemat (1956), Kostiuk (1930), Kubiena (1931-35), Michoustin (1956), Samtzewitsch (1955), and Niethammer (1937). The findings of these scientists does not differ significantly from our own observations and will therefore not be discussed any further.

Bacteria and actinomycetes are of much greater significance from many standpoints in this soil than the fungi. In the first place a series of ray fungi with intensive color (also yellow and blue) and melanin exudations seem to be typical. The bacterial flora is also more species abundant in chernozem than in other soils. Azotoboder and nitrifying bacteria are particularly abundant here. The bacteria have the predominant part in cellulose decomposition. In spite of this, fungi of the genera *Stysanus*, *Chaetomium*, and *Penicillium* are also measurably involved in the decomposition of cellulose containing plant residues. Trichoderme, which also decompose cellulose, occurs only in the spring or in the fall at the suitable water content of soil (30%). The

bacteria also play here the major part in pectin decomposition. Of the fungi, *Pullularia* is fairly active in this respect, while *Mucora* species are in the background (Wieringa 1955, Lambina 1956). Just as for the schizophyta, the fungal flora of the black earth also differs from the soils discussed previously. Of the species that occur there is a series which is characteristic for chernozem alone, a number of further forms, however, for sufficiently chalk-containing and xerothermal sites in general. *Cunninghamella elegans, Stysanus stemonites, A Aspergillus candidus, Aspergillus flavus, Aspergillus ochraceus, Penicillium italicum, Penicillium corymbiferum, Penicillium terrestre, Penicillium biforme, Penicillium lilacanium, Spicaria violacea,* and *Spicaria elegans* are in themselves specific for chernozem. Further species of the genera *Chaetomium, Gliocladium, Spicaria, Aspergillus,* and *Cunninghamella* are in general characteristic for xerothermal, chalk-containing soils. The fungi which are typical for the high bog and podsol are missing in chernozem. Primarily, the acid formers under the fungi not dominate so greatly anymore. Where there are still acids being formed, there are enough bases in the soil to neutralize them. Besides, there are so many species of organisms which decompose the acids more or less completely. This is also true of the inhibitors formed by the few fungi, insofar as they are not more unstable under the conditions of the pannonic climate.

The picture of the microflora, particularly of the fungi, naturally also /60
changes in the black earth. Particularly significant is the summer aspect with various species of *Aspergillus* and *Gliocladium*. In late fall, *Stysanus* forms the picture of the Mycocoenose. The winter aspect is not very characteristic with various penicillins.

Rendzina Soils of the Pannonic Area

Mould Rendzina and mould-like Rendzina are very similar in their microflora to chernozem, insofar as we deal with more or less xerothermal sites. We see this particularly well in the rich development of *Azotobacter chroococcum.* In any case, for mould-like Rendzina under *Pinus nigra* the upper part of the humus layer can be so poor in calcium that Azotobacter may no longer be detectable in this layer. But it develops on the same sites below where the humus layer is penetrated by chalk or dolonite. The Azotobacter development appears to be inhibited by extreme drying out in the protorendzina. All Rendzina soils in this

group are characterized by more or less abundant occurrence of nitrifying agents. *Pseudomonas fluorescens* and other species of the genus, which often multiply intensively in the chernozem, appear to favor under these soils deeper lying forms of mould rendzina. According to investigations up to now the species abundance of cellulose decomposing bacteria is not very great. Also the actinomycetes are represented by fewer species than in the chernozem; many of them have the capacity to form melanin. The pannonic rendzinas show very great similarity with the chernozem in their fungal flora, whose forms intensively participate in cellulose decomposition as well as pectin decomposition. *Chaetomium, Gliocladium, Stysanas, Aspergillus,* and a few penicillins are very active cellulose decomposers; these are also found in chernozem. A few of these forms are still active at an actual water content in the soil of 15%, particularly aspergillus. The "aspergillus aspect" on which other species of the genus participate besides *A. candidus* is characteristic for the microflora of the sites in June and July. *Gliocladium, Penicillium lilacinum,* and *Spicaria violacea* also belong to the summery soil microflora. *Stysanus* develops in chernozem more abundantly only in the fall. The wintery fungal flora shows us besides *Trichaderme* a series of species, which however, are not typical for the microflora. Under *Pinus nigra,* insofar as it is under a dense stand individual typical species of the pannonic rendzinas may also be missing in the summer in the upper cm of the humus layer.

Meadow Soils

Although these sites cannot at all be termed xerothermal, the species composition of the meadow soils link up partly to the microflora of the chernozem. Azotobacter as well as nitrosomonas are present in the brown and the grey meadow soil. Cellulose decomposition is largely dominated by bacteria, mostly of the genus *Cellulomonas.* Otherwise the bacteria flora does not appear to be specific in any way for the meadow soils, according to investigations to the present. Also pectin decomposition appears to be largely the work of bacteria, the mucorinees are, namely, not very strongly represented in the fungal flora. Typical fungi, which also occur in the chernozem, such as *Stysanua stemonites, Gliocladium penicillioides, Aspergillus flavus,* and *Spiceria violacea.* may be isolated more or less abundantly according to the time of year, from grey, as well as brown meadow soil. *Trichoderme koningii* is less abundant than in podsol, but is more /62 strongly represented than in chernozem. Fungal forms are also found in soils

of humid range of climate, as for example *Penicillium griseum, P. melinii, P. rubrum,* and *P. chrysogenum.* Observations up to the present have not disclosed any influence on the site conditions by exudation products of the microbes. Depending on the time of year the microflora of these soils also exhibit different aspects. This is shown particularly clearly by the fungi. During the spring *Trichoderme* multiply enormously. In the summer *Aspergillus, Gliocladium,* and *Spicaria* appear more distinctly. The following winter aspect brings various nontypical penicillins.

Parachernozem

The microbiological difference between chernozem and parachernozem is considerable in spite of a series of mutual properties. Thus, for example, *Azotobacter chroococcum,* may as a rule be found only on cultivated plains which are sufficiently lined. The fixation of atmospheric nitrogen appears to proceed through clostridien insofar as it is concerned with freely living organisms. Besides *Cellulomonas,* there are a series of fungi concerned with cellulose decomposition. Nitrosomonas could be isolated from most of the investigated sites, but in low amounts, just as for the chernozem. The difference between chernozem and parachernozem was shown clearly even from the first orienting investigations of the actinomycetes flora (see table). Under the fungi, *Cunninghamella, Aspergillus,* and *Gliocladium* remind one very much on the fungal flora of chernozem. On the other hand mucorinees may be isolated in layer numbers from parachernozem. Most of the forms of this group decompose hemicelluloses and pectins. The fungi are more active in cellulose decomposition in this soil than in the black earth, particularly forms of the genera *Cephalosponium, Scopulariopsis, Chaetomium,* and *Gliocladium.* Trichoderms have significance in this soil only at the time of maximum water. No significant exudation products of the microbes can be observed in soil type either, although numerous fungi are capable of forming inhibitors.

Xeroranker

The microflora of this soil type may be differentiated from all the previously discussed soils of the pannonic area. This is shown already by the complete absence of azotobacter and nitrosomonas. Nitrogen fixation by clostridiem has until now not been possible to establish with sufficient assurance. Cellulose

decomposition is dominated to a significant extent by the bacteria *Cellvibrio* and *Cellulomonas*. The isolation of really characteristic bacteria is yet to be achieved. Of the fungi which participate in cellulose decomposition only trichoderme plays a significant part in the winter; during the summer *Chaetomium*, *Glioclodium* and a series of other forms are far more active in this direction. The summer aspect is characterized besides by the appearance of *Aspergillus*. At the time of increased moisture, there develop fungi of the podsol-biocoenose, such as *Penicillium griseum*, *Penicillium canescens*, and *Trichoderme glauca*. The ecologically effective microbe exudations, such as acids and inhibitors, do not come to their full effect here either.

Terra Fusca

It was not possible until now to find micro-organisms which are characteristic only for the terra fusca. With regard to the species related composition of the microflora, this soil type appears to be between the oligotrophic brown earth, pseudogley, and chernozem. Azotobacter could often be isolated from /63 this soil. Also nitrosomonas may be found, at least in the upper cm of terra fusca. The fixation of atmospheric nitrogen is for the most part carried out by clostridiem. The bacteria are much more active in cellulose decomposition than the fungi. For the fungi, the microbiological position of terra fusca is between the previously named soil types. Thus numerous fungal forms occur in terra fusca of lightly acid soils, such as *Trichoderme*, *Zygorrhynchus*, *Scopulariopsis*, *Alternaria*, *Penicillium Thomii*, and *Penicillium melinii*, but also forms of the chernozem or rendzine are found here such as *Gliocladium*, *Penicillium italicum*, and *Penicillium citrinum*. This concurrence of forms of ecologically quite different sites hardly permits the hope of finding microbe systems which would be specific for this site.

Solonchak

The high pH values also have an effect on the condition of the microflora. Significant is the odd isolations of azotobacter, which were also confirmed by the findings of Wenzel (1934). There was little that was characteristic that could be isolated from the rest of the microflora, as far as the bacteria are concerned. A few fungi are also known only from single findings. Besides the

the bacteria, only *Cladosporium lignicola* and *Penicillium lilacinum* participate in the decomposition of plant residues. The question of an influence of the microflora on the ecological conditions of the site is for this soil just as unclarified as the question of the nitrogen cycle.

Summary

1. An attempt was made to characterize soil types or soil types groups microbiologically. It was found that single samples were insufficient for the microbiological characterization of soils. The investigations must be conducted with repeated sampling in more or less regular intervals for at least a year. The numerical results of such "yearly cycles" in curve form yield quite characteristic pictures.

2. The soil types were arranged in microbiological-ecological groups on the basis of the properties of the yearly cyclic mass changes of the microbes. For a part of the soil types it was clearly shown that the water budget played a decisive part in the mass development during the course of the year.

3. The organisms of the physiological groups deviate in their mass development from those of the total germ number. This deviations, however, can furnish further microbiological characteristics for the soil types or soil type groups, as demonstrated by this work.

4. With the consideration of the qualitative composition of the microflora of the soils, the significance of chemical site properties is at least as great as the influence of the water budget.

It turned out that certain species inventories of the microbes are characteristic for certain soil types. Sociologically those groups of the organisms correspond approximately to the synusiae. Just as characteristic for the soil types or soil type groups is a specific change in "aspects" of the microflora conditional on the time of year.

Furthermore, the discussion of the individual soil types also determined the /64
individual soil types also determined the effect of the activity of the microphyten on the site conditions at any time. Only by these determinations does the qualitative microbiological analysis of the soil earn practical significance.

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